Speech Theodor Kockelkoren - Advancing Knowledge and Safety: Revisiting Salt Cavern Research and Energy Storage Solutions Five Years On (October 15th 2024)

Introduction: The 2019 Workshop and Its Importance

In 2019, five years ago, the ministry of Economic Affairs and Climate policy initiated a workshop on the re-use and abandonment of salt caverns. A timely initiative, since at the time recent incidents had made clear our understanding of the technical issues associated with the abandonment of especially the very large caverns was insufficient. The workshop was also timely as it was emerging that large scale energy storage in salt caverns will most likely become a key element of our future energy system. The workshop organized by ECN.TNO and DEEP.KBB brought together a range of experts, operators and authorities from the Netherlands, France and Germany.

Reflections on the 2019 Workshop: Addressing Technical Gaps and Future Energy Needs

I am very pleased that today again, we are together as a diverse group of experts, operators and authorities. It shows the broad, consistent involvement of all relevant parties, committed to further developing, indeed deepening, of our knowledge. As inspector general of mines I am very pleased by this commitment. In my observation it is a major step forward. It must have been a long time since for such a prolonged period, and such focus we have been trying to push forward the boundary of our knowledge.

Many of you will remember that five years ago it had become painfully clear that caverns can also frack and migration paths of brine between different layers and between caverns can occur. Before that time there was a consensus among operators and consultants that after cavern closure permeation would be the mechanism that would occur once the brine pressure reaches the lithostatic pressure. This consensus had formed despite the long standing controversy on this topic in the scientific community. State Supervison o f Mines (SSM) had already in the 2017-2019 period initiated further scientific research (KEM17) into this controversy. The workshop in 2019 contributed to the initiation of subsequent research by operators in the so-called Cavern Closure Consortium (CCC).

Key Learnings from KEM17: Leakage Mechanisms in Over-Pressured Salt Caverns

As you all will know KEM17 conducted research at three scales to answer the question of leakage mechanisms in over-pressured salt caverns: at the micro-scale, the cavern-scale and larger scale salt structures (the 'dome-scale'). The reports were published beginning of 2020. At the micro-scale the research focused on the initial mechanical properties of the salt and how these properties together with the stress field evolve over time. The role of impurities in the layers was part of the scope as well. The research concluded that homogeneous permeation is not the most obvious leakage mechanism. Rather, it found indications that preferential leakage paths might be more realistic. It pointed to the need for further research.

At the cavern-scale key research questions were how quickly the pressure would build up after closure and whether permeation could keep up with the pressure build up. Assessing the minimum principal stress, in our context the fracturing pressure, was part of the scope. The research showed that in shallow caverns a safe equilibrium pressure may be reached making hard closure of the cavern a possible way forward. In deep caverns the pressure increase could possibly be too rapid to be accommodated by permeation. The research also showed that in high caverns the potential for overpressure is large. Naturally, SSM is very concerned about this. We also noted in the research an implied risk: the minimum principal stress may actually be lower than expected.

The dome-scale research focused on the rheology of salt bodies: how do the bodies deform and flow under a pressure field? The research showed for example that potentially significant differential stresses appear near the top of a salt structure, close to the lateral edges of a salt body and near anhydrite stringers or weak KMg-salts.

The Role of the Cavern Closure Consortium in Advancing Research Integration

Overall KEM17 made clear that with the at the time current knowledge it cannot be predicted with certainty if a deep cavern will leak with slow permeation, a localized leakage path or hydraulic fracture. Also, it became apparent that the knowledge at the micro, cavern and salt body scales is not integrated enough, and processes on all three levels influence the leakage mechanism. More research is needed.

Following KEM17, the Cavern Closure Consortium (CCC) conducted further research. The CCC focused among other things on integrating the knowledge at the three mentioned scales. Today and tomorrow they will present their research, outlining the research questions and their findings and conclusions.

Given the concerns SSM has regarding the very large caverns in Groningen, we also welcome the discussions regarding the associated dilemma's of the very large caverns in Groningen. What options are realistically on the table? Does the research point to a path were as much brine is drained as possible ensuring minimum stability risk over time, but resulting in maximum subsidence? Or does the research indicate the stability risks can be managed by first filling caverns and subsequently close them preventing maximum subsidence risk? Does the research indicate whether and how the risks associated with this path can be managed? Naturally, the answers to these questions may also be relevant to very large caverns in Germany and Denmark.

Also, even if the likelihood of one of the large caverns becoming instable is very small, SSM thinks it prudent to be prepared in the very unlikely case this happens. We think more discussion among us as well as research is needed to understand the nature and time scale of the upward migration of a cavern instability.

Hydrogen Storage in Salt Caverns: Research and Unanswered Questions

Since the KEM17 report was published operators have adapted. Nobian has submitted plans for Haaksbergen for potentially very large caverns. The way closure of such caverns is to be done safely is given our current knowledge still buried underground. As a result, there has been put a limit to the size of these caverns. And only after Nobian will have conducted further research and submitted a closure plan that SSM deems sufficiently safe, the Haaksbergen caverns can grow beyond the enstated limit.

Frisia has adapted their salt mining approach for Havenmond. Their very deep caverns will close already partially during the production phase. In this way subsidence occurs earlier while at the same time they gain a better understanding on the expected subsidence. Given that subsidence is a key risk

in the Waddenzee environment, Frisia's approach has merits. However, the new sea level rise scenario's have led to a new decision (the 'Gebruiksruimtebesluit') by the Dutch government on how much subsidence in the Waddenzee is allowed. This decision has important implications for mining under the Waddenzee. SSM will assess the new situation as a result of the government's decision very carefully.

In the past five years research has also been done into the questions surrounding large scale energy storage, in our context hydrogen storage in salt caverns. In 2018 TNO estimated initially that at least 50 or potentially more than 200 caverns would be necessary to enable the large scale storage demand necessary for the future Dutch energy system. Since then, more research has been conducted. The expected number of storage caverns remains at the lower end of this range, yet remains highly uncertain.

For SSM important research questions will need to be answered. For example, how should the leakage mechanisms be assessed in a cavern filled with the smallest possible molecule, Hydrogen? What is the effect in a system of caverns of the fast and slow cycle pumping of the Hydrogen in and out of the caverns? How could a instable cavern influence the complete field of caverns? Could hydrogen possibly react with anhydrite under the influence of microbes? When abandoning a storage cavern eventually, how will it be filled and how can this be done safely?

Balancing Energy Storage and Environmental Risks: The Potential of North Sea Caverns

Meanwhile, research has also been initiated to assess the potential for large scale energy storage in caverns created under the North Sea. I think this is wise. From an engineering perspective it is not immediately obvious. However, when one looks at the cumulated subsidence impact of creating many storage caverns in Groningen, the impact of the associated above ground installations and piping (including the associated safety hazards) and the existing large scale impact of the former Groningen gas extraction, identifying and researching alternatives (to caverns in Groningen) under the North Sea is actually common sense.

Learning from the Groningen Gas Debacle: Prioritizing Safety Over Financial Interests

This brings me to my last perspective on what has happened in the past five years. The Groningen gas debacle has led amid the large, dramatic impact on people in the province, to a report titled 'Groningers boven gas' presented in 2023 by a parliamentary enquiry. The title, literally saying 'Groningers above gas', signifies what in the eyes of the enquiry needs to change: the wellbeing, the interest of the people in the Groningen province needs to be prioritized above the financial interests of Groningen gas. The enquiry had found that in the decades before this had been the other way round: financial interests had always prevailed over the interests of the people in Groningen.

The enquiry concluded that in the previous decades the possible hazards and risks associated with the gas extraction were first denied, then downplayed and finally, when that was no longer possible, not taken seriously enough. The enquiry stated that government and oil companies had neglected their duty of care. Ladies and gentleman, how to avoid such disaster and damning conclusions?

Open and Inclusive Risk Management: A Duty to Share Knowledge and Engage Stakeholders

For the context of today, I think two key learnings stand out. First, avoid risk management to be a closed shop. Second, we all have a duty to care for safety and therefore a duty to ensure sufficient, and sufficiently strong knowledge.

Today is very much about the second learning: the spirit of these proceedings are sharing knowledge, identifying areas that require more research, and committing to ensure our knowledge in the end is sufficiently strong. To some extent, today is also about the first learning, as today's proceedings are open, they are international, they instill an atmosphere in which all perspectives are welcome to be brought forward, where controversy flowers in constructive scientific discourse.

However, the first learning requires more. It brings an imperative on all of us. We need to work hard to ensure that our knowledge and today's sharing of it, is also shared with all relevant stakeholders, most notably people in Groningen whose wellbeing was submitted for so long to financial interests. We need to work hard that they are sufficiently involved in our efforts to strengthen our knowledge. I am sure the operators and the ministry of Climate and Green Growth will recognize this point. State supervision of mines certainly does. Acting upon this recognition, however, is not necessarily easy. Can I count on your commitment?

I wish you all very fruitful, intense and constructive proceedings.